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BEFORE THE BOARD OF OIL, GAS AND MINING
DEPARTMENT OF NATURAL RESOURCES
STATE OF UTAH

IN THE MATTER OF THE APPLICATION OF WESTWATER FARMS, LLC FOR ADMINISTRATIVE APPROVAL OF THE HARLEY DOME 1 SWD WELL LOCATED IN SECTION 10, TOWNSHIP 19 SOUTH, RANGE 25 EAST, S.L.M., GRAND COUNTY, UTAH, AS A CLASS II INJECTION WELL	**SUPPLEMENT TO REQUEST FOR REHEARING AND MODIFICATION OF EXISTING ORDER, AND IN THE ALTERNATIVE, REQUEST FOR A STAY OF THE ORDER ISSUED ON JANUARY 13, 2011** **Cause No. UIC-358.1**

Living Rivers ("LR") respectfully supplements its request for rehearing and modification of the Findings of Fact Conclusions of Law and Order signed by the board chairman on January 13, 2011. This supplementation is to make of record the expert opinions and report of Professor Kip Solomon, Chairman of the Department of Geology, University of Utah, referenced in LR's original motion for rehearing and modification to the Board. A copy of Professor Kip Solomon's expert report is attached hereto as Exhibit A.

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Respectfully submitted this 22nd day of February 2011.

[signature]   *[signature]*

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Patrick A. Shea   Jacque M. Ramos
Counsel for Living Rivers   *Counsel for Living Rivers*

MAILING CERTIFICATE

I hereby certify that I mailed a true and correct copy of the foregoing

SUPPLEMENT TO REQUEST FOR RECONSIDERATION AND IN THE

ALTERNATIVE REQUEST FOR A STAY OF THE ORDER ISSUED ON

JANUARY 13, 2011, postage prepaid, this 22nd day of February 2011 to the following:

Steven F. Alder
Assistant Attorney General
Board of Oil, Gas and Mining
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Michael S. Johnson
Assistant Attorney General
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Grand County
Road Development
125 East Center
Moab, Utah 84532

United States Bureau of Land Management
Moab Field Office
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Moab, UT 84532

Federal Highway Administration
2520 West 4700 South, Suite 9-A
Salt Lake City, UT 84118-1847

Mid-America Pipeline Company
171 7 South Boulder Avenue
Tulsa, OK 74121-1628

Utah School and Institutional Trust Lands Administration
675 East 500 South, Suite 500
Salt Lake City, UT 84102-2818

Petro Resrc Corp.
777 Post Oak Blvd, Suite 910
Houston, TX 77056

RMOC Holdings, LLC
921 East Belleview Avenue
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Shiprock Helium, LLC
PO Box 51166
Amarillo, TX 79159

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Red Lodge, MT 59068-0790

Bill Love
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United States Fish and Wildlife Service
Attn: Larry Crist
Utah Field Office 2369 West Orton Circle, Suite 50
West Valley City, Utah 84119

EXHIBIT A

D. Kip Solomon, Ph.D, PG
2355 East 900 South
Salt Lake City, UT 84108

February 20, 2011

Patrick A. Shea
252 South 1300 East, Suite A
Salt Lake City, Utah 84102

Dear Pat:

I have reviewed the hydrogeological aspects of the application from Westwater Farms to inject produced water into the Wingate Formation in the vicinity of Harley Dome. I have also reviewed supporting materials including the hydraulic stimulation report, the water quality report, structural contour maps, etc.

In order to evaluate the potential impact of this injection well on the hydrogeology of the Glen Canyon Group Aquifer, I have simulated the pressure field that would develop radially outward from the well. I have utilized the Theis Equation that is commonly used for evaluating aquifer tests that involve an extraction well and 1 or more observation wells. To use the Theis Equation in forward mode, estimates of the following parameters are needed: aquifer transmissivity (T), aquifer storativity (S), and injection rate (Q). The transmissivity was calculated using a permeability of 20 millidarcies (David K. Dillon, letter report dated July 20, 2010), a fluid density of 1033 kg/m^3, an aquifer thickness of 334 ft, and a fluid viscosity of 9.86×10^{-4} kg/m/s (appropriate for water at 70 °F), to be 19 ft^2/day. The aquifer storativity (S) is a function of the compressibility of the formation, the porosity, and compressibility of water. While the supporting material provides a porosity estimate, and the compressibility of water can be assumed to be about 4.5×10^{-10} Pa^{-1}, I can find no site-specific estimates of the compressibility of the Wingate Formation (which I judge to be a major deficiency in the supporting data). The storativity for the Navajo Sandstone (which is also an aeolian sandstone) was reported by Heilweil et al. (2000) to range from 0.0025 to 0.0007. After adjusting this for the lesser thickness of the Wingate (334 ft versus approximately 1000 feet) yields estimates of 0.0008 to 0.0002 for the Wingate. In the absence of a site-specific value for S, I have assumed a value of 0.001 as this is also considered to be the upper limit for a confined aquifer (Lohman, 1979.) The injection rate was set to 4.5 barrels per minute (David K. Dillon report dated July 20, 2010) which is approximately 36,400 ft^3/day.

TheTheis Equation assumes the aquifer is perfectly confined above and below, and is of infinite lateral extent. The geometric details of the actual aquifer could be incorporated into a standard numerical model such as MODFLOW or SEAWAT.

The outward propagation of pressure from the injection well is controlled by the ratio of the transmissivity to storativity (T/S), which is known as the hydraulic diffusivity. When the hydraulic diffusivity is large (because T is large and/or S is small) the pressure mound

will be spread out over a larger lateral extent than compared to a smaller hydraulic diffusivity. The figure below shows the simulated pressure distribution for a transmissvity of 19 ft^2/day and a storativity of 0.001. This transmissivity is derived from a permeability of 20 millidarcies, consistent with the value reported by David K. Dillon (letter report dated July 20, 2010. It is important to point out that this simulation produced a pressure at the injection well that exceeds the 360 psi limit recommended by David K. Dillon. The simulation agrees relatively well with hydraulic stimulation test conducted by BJ Services after an injection of about 1 hour (i.e. the time at which the stimulation test reached an injection of 5 bpm), but suggests that a prolonged injection at 4.5 barrels per minute will exceed the recommended pressure limit. Nevertheless, an injection rate of 4.5 barrels per minute was utilized in the simulation because this is the value recommended by David K. Dillon, and it would be possible to inject at this rate if the permeability is somewhat higher than 20 millidarcies and/or if multiple injection wells were utilized.

As shown below, the simulated pressure rise at a distance of 5 miles after 5 years of injecting 4.5 barrels per minute would about 0.08 psi, which is equivalent to a rise in the potentiometric surface of about 0.18 feet.
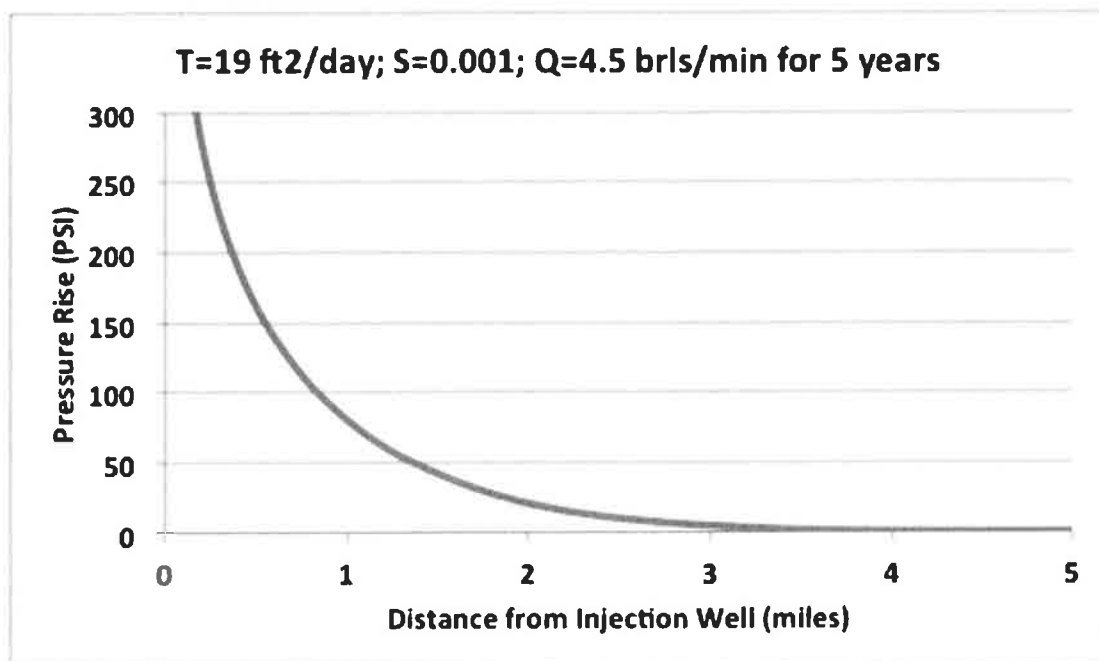

Figure 1. Simulation of pressure mounding that results from injecting 4.5 barrels per minutes for 5 years. This simulation utilizes a transmissivity of 19 ft^2/day (which is derived from a permeability of 20 millidarcies), and a storativity of 0.001. These values are considered to be the best available estimates, although no site-specific values for storativity have been presented.

Because the hydraulic properties of the Wingate in the vicinity of the injection well have uncertainty associated with them (only a single measurement of permeability is available

and no measurements of storativity), I have also simulated the pressure distribution using more extreme, but still realistic values. For example, aquifer testing of the Navajo Sandstone in the vicinity of St. George Utah resulted in transmissivities that ranged from 100 to 19,000 ft^2/day. Figure 2 below shows the simulated pressure distribution after injecting 4.5 barrels per minute for 5 years using a transmissvity of 100 ft^2/day and a storativity of 0.0005. In this case the pressure at the injection wells stays below the recommended limit of 360 psi. The pressure rise at a distance of 5 miles is 7.9 psi which is equivalent to a rise in the potentiometric surface of about 18 feet.
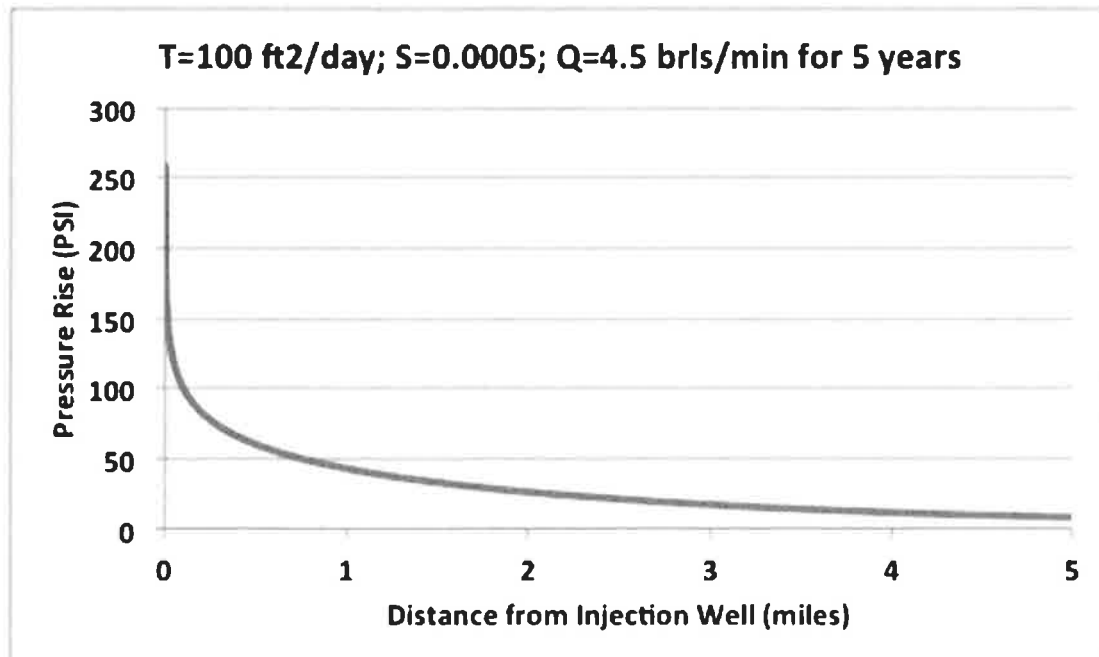

Figure 2. Simulation of pressure mounding that results from injecting 4.5 barrels per minutes for 5 years. This simulation utilizes a transmissivity of 100 ft^2/day (derived from a permeability of 104 millidarcies), and a storativity of 0.0005. These values are considered to be realistic, but result in a hydraulic diffusivity that is higher than the best available estimate.

While the simulation presented above does not take into account the geometric details of the aquifer, it does provide the basis for evaluating the potential impact of the injection operation on the regional hydrogeology. It is important to understand that although the Windgate outcrops near the Colorado River (approximately five miles away) at an elevation that is higher (800 feet according to David L. Allin) than at the proposed injection site, it is not necessary to raise the pressure head 5 miles away by that same amount (i.e. 800 feet) in order affect regional groundwater flow near the Colorado River. The elevation of the Colorado River at a point nearest to Harley Dome is 4323' (Rebuttal Exhibit 3; notes by David L. Allin December 1, 2010). The static water level in the Wingate at the injection well is 4275' (Rebuttal Exhibit 3; notes by David L. Allin December 1, 2010). In order to reverse the northward direction of groundwater flow to southward (towards the Colorado River) it is only necessary to raise the water level in the

injection well to greater than 4323 (i.e. 48 feet.) Figure 3 is a cross section that starts at the injection well and terminates at the Colorado River (at the point labeled "Nearest outcrop 5.8 miles Jw 4350' near river level"; Rebuttal Exhibit 3; notes by David L. Allin December 1, 2010). The redline is an estimate of the current potentiometric surface that connects the two known water levels; the Colorado River at 4325' and the injection well at 4275'. Superimposed on this cross section is the simulated potentiometric surface after 5 years of injecting 4.5 barrels per min. Figure 4 is similar to Figure 3, except it utilized the larger hydraulic diffusivity value discussed previously. In both Figure 3 and Figure 4, the slope of the simulated potentiometric surface is towards the river for most of the cross section as a result of the injection. When the higher hydraulic diffusivity value is utilized, Figure 4 illustrates that existing Wingate Formation fluid would begin discharging into the Colorado River. The environmental impact of such discharge is not known as it depends on both the rate of discharge and the quality of the Wingate Formation water near the river. Nevertheless, this analysis illustrate my concern that the buildup of fluid pressure as a result of an injection could reverse the regional hydraulic gradient and cause existing Wingate Formation water to discharge into the Colorado River. It is important to note that I am not particularly concerned about the actual migration of injected fluid a distance of over 5 miles as this transit time is likely to be far greater than the life of the injection well. Rather, my concern is over the propagation of fluid pressure that might reverse what currently appears to be northward moving regional groundwater flow.

Recommendations:

1. A three dimensional numerical model of groundwater flow should be developed to further refine the possibility of reversing the direction of groundwater flow near the Colorado River. The model should account for the geometry of the aquifer and should consider the variations in fluid density that likely exist between the Colorado River and formation water at the injection well. The model should also be capable of simulating solute transport so that potential salt loading to the Colorado River can be assessed.

2. A monitoring well should be installed that penetrates the Wingate Formation and is located approximately 1 mile to the southeast of the injection well (between the Colorado River and the injection well.) This well can be used to obtain an estimate of the transmissivity and storativity of the aquifer that is integrated over a reasonably large scale. Aquifer parameters obtained from this well could be used to update the numerical model.

3. A shallow monitoring well should be installed into the Wingate Formation approximately 0.25 miles northwest of the "Nearest outcrop 5.8 miles [of] Jw 4350' near [Colorado] river level" noted on the structural contour map prepared by David L. Allin, December 1, 2010. This well will help define the direction of groundwater flow in the Wingate, along with the quality of water in the Wingate near the Colorado River.

4. Monitoring wells in the Wingate Formation at distances of approximately 1 and 5 miles from the injection well, could be used to establish a limit on the pressure

build up from the injection well. For example, as long as the hydraulic head 1 mile from the injection well is lower than the head near the Colorado River, then it is unlikely that Wingate Formation water will discharge into the River. The simplified simulation presented in this report suggest that this will be the case for an injection rate less than about 11,300 ft^3/day (1.4 barrels per min) after 5 years, but not for larger injection rates. It would be reasonable to keep the head at 1 mile at least 10 feet lower than the Colorado River; however, I recommend that an exact criterion be established using a three-dimensional flow and transport model. The end goal is to prevent Wingate Formation water from discharging into the Colorado River as a result of the injection operation.

5. The hydraulic head in fluid bearing zones above the Wingate should be monitored during injection in order to evaluate the extent to which the Wingate Aquifer is completely confined. Ideally such monitoring wells would be as close a possible to the injection well and be finished in the Kayenta Formation. However, existing wells in the area may be a cost-effective alternative to installing new monitoring wells above the Wingate Formation.

References

Heilweil, V. M., G. W. Freethey, B. J. Stolp, C. D. Wilkowske, and D. E. Wilberg, Geohydrology and numerical simulation of ground-water flow in the central Virgin River Basin of Iron and Washington Counties, Utah, State of Utah Department of Natural Resources, Technical Publication No. 116, 2000.

Lohman, S. W., Ground-water hydraulics: U. S. Geological Survey Professional Paper 708, 70 p., 1979.

Respectfully Submitted,

D. Kip Solomon

REGISTERED PROFESSIONAL GEOLOGIST
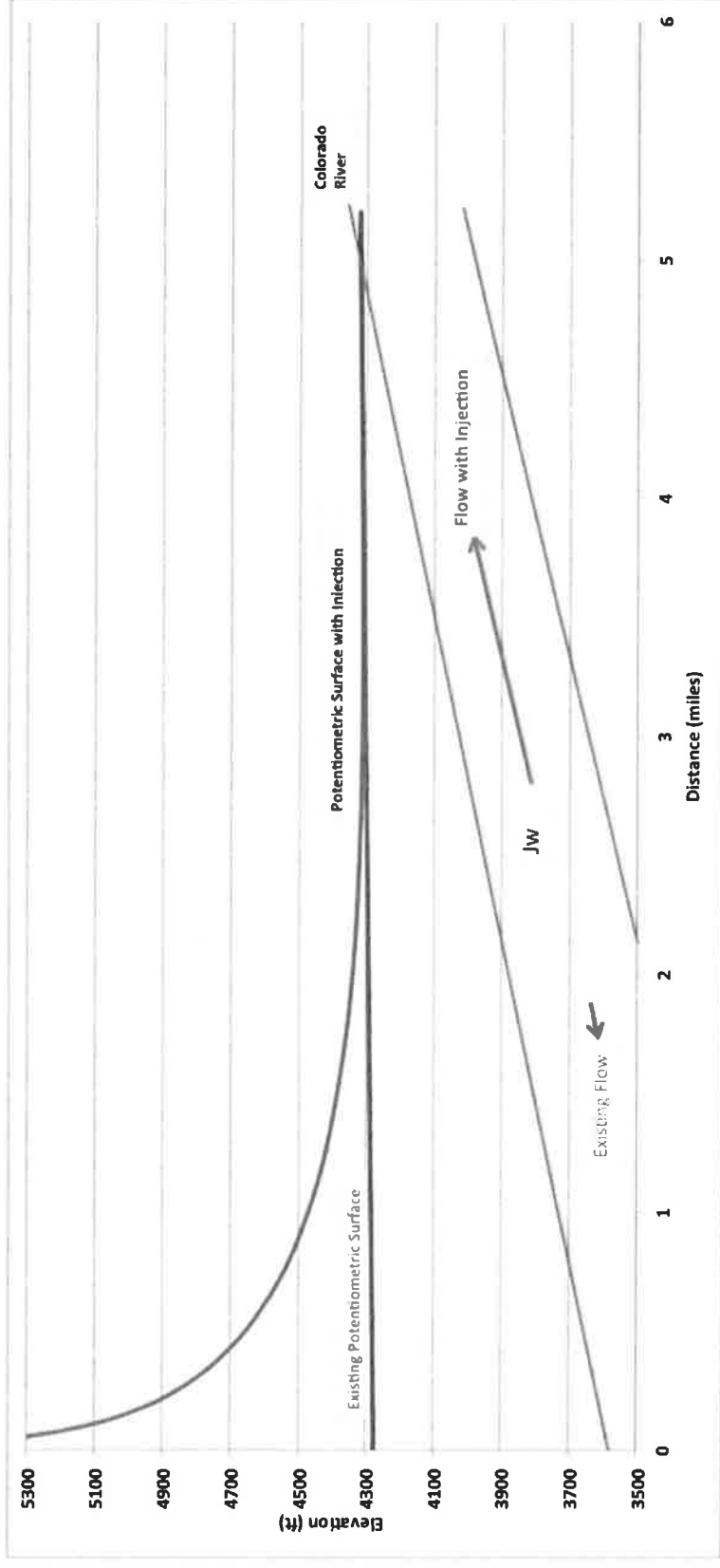D. KIP SOLOMON
NO. 5555493-2250
STATE OF UTAH

Figure 3. Cross section that extends from the injection well (distance = 0) to the Colorado River. The red lines shows the existing potentiometric surface that was estimated using the two known water levels (4275 at the injection well and 4323 at the Colorado River.) The blue line is the simulated potentiometric surface for pumping 4.5 barrels per minute for 5 years with a transmissivity of 19 ft^2/day and a storativity of 0.001. Also shown are the upper and lower contacts of the Wingate Formation (Jw). The simulated potentiometric surface slopes towards the Colorado River over most of the cross section and indicates that the injection could reverse the direction of regional groundwater flow.
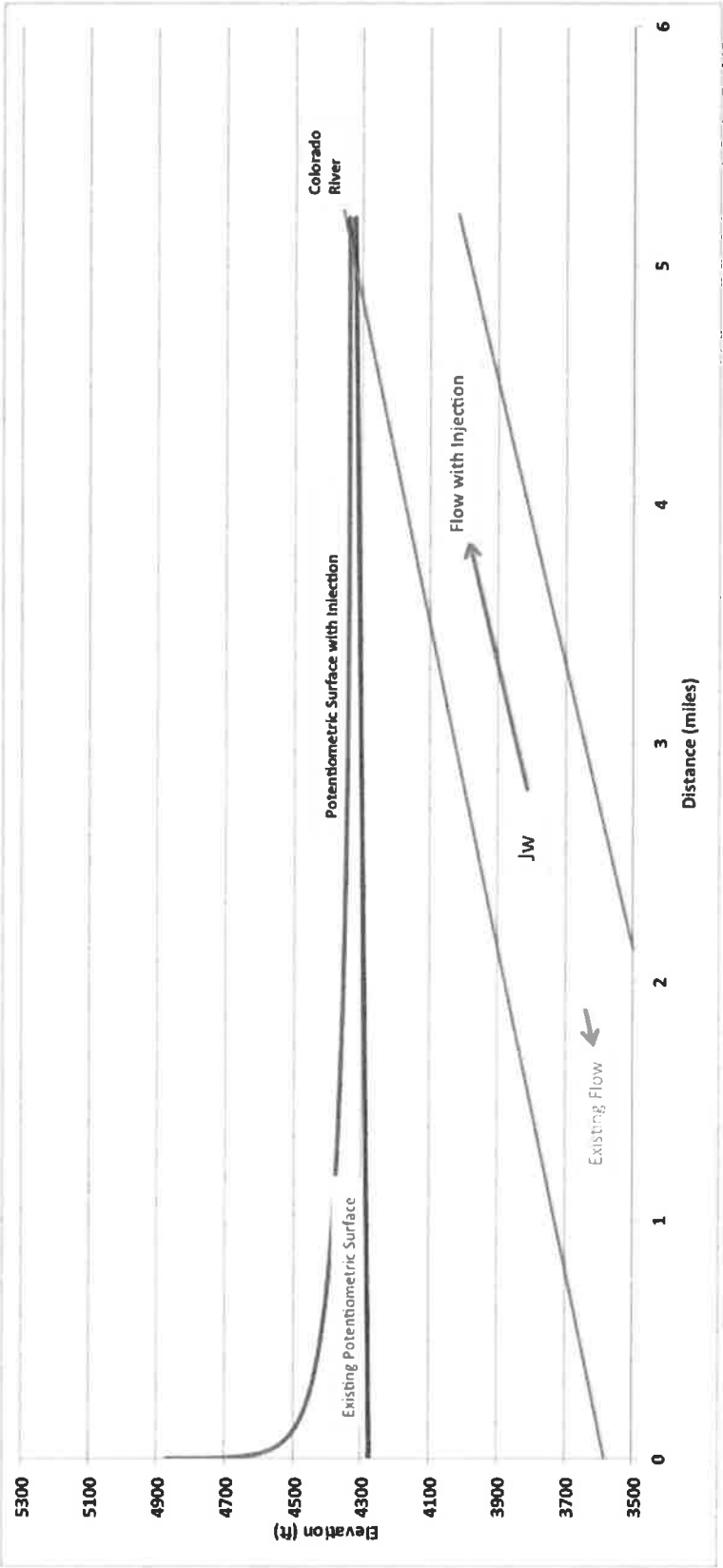
Figure 4. Cross section that extends from the injection well (distance = 0) to the Colorado River. The red lines shows the existing potentiometric surface that was estimated using the two known water levels (4275 at the injection well and 4323 at the Colorado River.) The blue line is the simulated potentiometric surface for pumping 4.5 barrels per minute for 5 years with a transmissivity of 100 ft²/day and a storativity of 0.0005. Also shown are the upper and lower contacts of the Wingate Formation (Jw). The simulated potentiometric surface slopes towards the Colorado River over all of the cross section and indicates that the injection could reverse the direction of regional groundwater flow. My concern is that this would in turn cause Wingate Formation fluid to discharge into the Colorado River.